CLAIMS

1. A method of producing a semiconductor device incorporating a capacitor structure that includes a ferroelectric thin film, comprising:

forming, on a single crystalline substrate having a surface suited for growing thereon a thin film layer of ferroelectric single crystal having a plane (111), a ferroelectric single crystalline thin film containing Pb and having a plane (111) in parallel with the surface of the substrate or a ferroelectric polycrystalline thin film containing Pb and oriented parallel with the plane (111) in parallel with the surface of the substrate, and part of a circuit of a semiconductor device, to thereby fabricate a single crystalline substrate having said ferroelectric thin film containing Pb and said part of the circuit of the semiconductor device; and

bonding said single crystalline substrate to another substrate on which the other circuit of the semiconductor device has been formed in advance, to couple the two circuits together to thereby obtain a semiconductor device incorporating a capacitor structure that includes a ferroelectric thin film.

2. A method of producing a semiconductor device according to claim 1, comprising:

(1) forming, on a single crystalline substrate, a ferroelectric single crystalline thin film layer containing Pb and having a plane (111) in parallel with the surface of the substrate, patterning said thin film layer to thereby form isolated ferroelectric thin films of a predetermined shape on the single crystalline substrate, forming one electrode of a capacitor of a predetermined shape positioned on said ferroelectric thin film, and forming part of a circuit of a semiconductor device on the single crystalline substrate, to thereby fabricate a single crystalline substrate having thereon said ferroelectric thin film containing Pb, said one

electrode and said part of the circuit of the semiconductor device;

(2) fabricating a semiconductor substrate having the other circuit of the semiconductor device formed;

(3) bonding said single crystalline substrate to said semiconductor substrate to couple the circuits of the two substrates together; and

(4) removing said single crystalline substrate to expose the ferroelectric thin film, and forming another electrode of the capacitor on the ferroelectric thin film that is exposed.

3. A method of producing a semiconductor device according to claim 1, comprising:

(1) forming an electrically conducting thin film layer on a single crystalline substrate having through holes, forming, on said electrically conducting thin film layer, ferroelectric single crystalline thin film containing Pb and having a plane (111) in parallel with the surface of the substrate, or a ferroelectric polycrystalline thin film layer containing Pb and oriented parallel with the plane (111) in parallel with the surface of the substrate, patterning said electrically conducting thin film layer and said ferroelectric thin film layer to thereby form isolated ferroelectric thin films of a predetermined shape and one electrode of a capacitor of a predetermined shape, forming another electrode of the capacitor on said ferroelectric thin film, and forming part of a circuit of a semiconductor device so as to pass through the holes in said single crystalline substrate, to thereby fabricate a single crystalline substrate comprising a capacitor structure constituted by said ferroelectric thin film containing Pb and a pair of electrodes holding the ferroelectric thin film therebetween, and said part of the circuit of the semiconductor device;

(2) fabricating a semiconductor substrate

having the other circuit of the semiconductor device formed; and

(3) bonding said single crystalline substrate to said semiconductor substrate to couple the circuits of the two substrates together.

4. A method of producing a semiconductor device according to any one of claims 1 to 3, wherein said ferroelectric material is PZT ($PbZr_xTi_{1-x}O_3$), PLZT ($Pb_yLa_{1-y}Zr_xTi_{1-x}O_3$), PLCSZT ((Pb, La, Ca, Sr)(Zr, Ti)O_3) or a substance derived therefrom by adding Nb thereto.

5. A method of producing a semiconductor device according to any one of claims 1 to 4, wherein as said single crystalline substrate, a single crystalline substrate having a plane (111) on which the ferroelectric thin film is to be formed, or a single crystalline substrate having an offset angle from the plane (111) is used.

6. A method of producing a semiconductor device according to claim 5, wherein said single crystalline substrate is an MgO or $SrTiO_3$ single crystalline substrate.

7. A method of producing a semiconductor device according to any one of claims 1 to 4, wherein as said single crystalline substrate, an α-Al_2O_3 single crystalline substrate having a plane (0001) on which the ferroelectric thin film is to be formed, or an α-Al_2O_3 single crystalline substrate having an offset angle from the plane (0001), is used.

8. A method of producing a semiconductor device according to any one of claims 1 to 4, wherein as said single crystalline substrate an $MgAl_2O_4$ single crystalline substrate having a plane (001) on which the ferroelectric thin film is to be formed, is used.

9. A method of producing a semiconductor device according to any one of claims 1 to 8, further comprising forming an electrically conducting thin film that will

form one electrode of the capacitor on said single crystalline substrate prior to forming said ferroelectric polycrystalline thin film layer.

10. A method of producing a semiconductor device according to claim 9, wherein said electrically conducting thin film is formed of Pt, Ir, Ti, Ru or an oxide thereof.

11. A method of producing a semiconductor device according to any one of claims 1 to 4, wherein as said single crystalline substrate a single crystalline silicon substrate having a plane {111} on which the ferroelectric thin film is to be formed or a single crystalline silicon substrate having an offset angle from the plane {111}, is used.

12. A method of producing a semiconductor device according to any one of claims 1 to 4, wherein as said single crystalline substrate, a single crystalline silicon substrate having a plane {100} on which the ferroelectric thin film is to be formed, or a single crystalline silicon substrate having an offset angle from the plane {100}, is used.

13. A method of producing a semiconductor device according to claim 11 or 12, wherein said ferroelectric thin film is epitaxially grown directly on the ferroelectric thin film-forming surface of said single crystalline substrate.

14. A method of producing a semiconductor device according to claim 11 or 12, wherein said ferroelectric thin film is epitaxially grown through a buffer layer formed on the ferroelectric thin film-forming surface of said single crystalline substrate.

15. A method of producing a semiconductor device according to claim 14, wherein said buffer layer is formed of MgO, yttrium-stabilized zirconia, $MgAl_2O_4$, CaO, $SrTiO_3$ or CeO_2, and said ferroelectric thin film is grown on the plane (111) or the plane (0001) thereof.

16. A method of producing a semiconductor device

according to claim 13, wherein an electrically conducting thin film is formed on said single crystalline substrate prior to forming said ferroelectric polycrystalline thin film layer.

17. A method of producing a semiconductor device according to claim 16, wherein said electrically conducting thin film is formed of Pt, Ir, Ti, Ru or an oxide thereof, and said ferroelectric polycrystalline thin film is grown on the plane (111) thereof.

18. A method of producing a semiconductor device according to claim 17, wherein said electrically conducting thin film is formed by stacking a plurality of layers formed of Pt, Ir, Ti, Ru or an oxide thereof.

19. A method of producing a semiconductor device according to claim 16, wherein said electrically conducting thin film is formed of $SrRuO_3$, YBCO or LSCO, and said ferroelectric thin film is grown on the plane (111) thereof.

20. A method of producing a semiconductor device according to claim 14 or 15, wherein an electrically conducting thin film is formed on said buffer layer prior to forming said ferroelectric polycrystalline thin film layer.

21. A method of producing a semiconductor device according to claim 20, wherein said electrically conducting thin film is formed of Pt, Ir, Ti, Ru or an oxide thereof, and said ferroelectric polycrystalline thin film is grown on the plane (111) thereof.

22. A method of producing a semiconductor device according to claim 21, wherein said electrically conducting thin film is formed by stacking a plurality of layers formed of Pt, Ir, Ti, Ru or an oxide thereof.

23. A method of producing a semiconductor device according to claim 20, wherein said electrically conducting thin film is formed of $SrRuO_3$, YBCO or LSCO, and said ferroelectric thin film is grown on the plane (111) thereof.